International Journal of Multidisciplinary Research and Growth Evaluation.

Production of briquettes from agro: Wastes/Coal blends and its effect on water boiling studies

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Article Info

ISSN (online): 2582-7138
Volume: 03
Issue: 03
May-June 2022
Received: 29-04-2022;
Accepted: 14-05-2022
Page No: 381-385

Abstract
The potential use of biomass as energy source in Nigeria is very high and this can be explained from the fact that about 80 % of Nigerians are rural or semi-urban dwellers that depend solely on biomass for their energy source. This research investigates the formulation of bio – coal briquette from groundnut shell, maize cob and rice husk and also studies how incorporation of binder affects the calorific values of the formulated briquettes. Some briquettes were formulated from the agro – waste with the incorporation of equal amounts of starch and coal (samples B, E and H) while in other briquettes, only starch was incorporated (samples A, D and G). Briquette samples C, F and I were formulated without any binder. The result also showed that the briquette samples (with or without binder) has higher burning rate and heating values than firewood. The results showed that all the briquette samples incorporated with starch or starch and coal binders boiled water at 16 min while firewood and briquette samples without binder boiled at 20 min except for maize cob briquette that could not boil water at 20 min. Incorporation of binders was found to increase the calorific values the briquette significantly. It was observed that incorporation of coal as binder had a significant effect only on the calorific value groundnut shell briquette samples. The result showed that briquettes will serve as a more effective substitute for firewood as it shows more combustion characteristics over firewood and the raw materials (agro – waste) are readily available.

Keywords: briquettes, Wastes/Coal, water boiling, Production

Introduction

Biomass, particularly agriculture residues seem to be the most promising energy resources for developing countries (Patomsok, 2008) [13]. Rural households and minority of urban dwellers depend solely on fuel woods (charcoal, firewood and sawdust) as their primary source of energy for the past decades (Onuegbu *et al*., 2010) [8]. Of all the available energy resources in Nigeria, coal and coal derivatives such as smokeless coal briquettes, bio-coal briquettes and biomass briquettes have been shown to have the highest potential for the use as suitable alternative to coal/fuel wood in industrial boiler and brick kiln for thermal application and domestic purposes. Global warming has become an international concern. Global warming is caused by greenhouse gasses which carbon dioxide is among the major contributors. It was shown that increase emissions of CO_2 have been drastically reduced owing to the fact that the rate of deforestation is higher than a forestation effort in the country (Yahaya and Ibrahim, 2012) [18]. In counties like Japan, China, India etc., it was observed that agricultural wastes (agro residues) can be briquetted and used as substitute for wood fuel. Every year, millions of tons of agricultural waste are generated (Wang *et al*., 2017) [16]. These are either not used or burnt inefficiently in their loose form causing air to the environment. The major residues are rice husk, corn cob, coconut shell, jute stick, groundnut shell, cotton stalk, etc. these wastes provide energy by converting into high density fuel briquettes. These briquettes are very cheap, even cheaper than coal briquettes. Adoption of briquettes technology will not only create a safe and hygienic way of disposing the waste, but turn into a cash rich venture by converting waste into energy and also contributing towards a better environment (Zubairu and Gana, 2014) [19].

The use of fuel wood for cooking has health implication especially on women and children who are disproportionately exposed to the smoke apart from environmental effects. Women in rural areas frequently with young children carried on their back or staying around them, the exposure is even higher especially when the cooking is done in an unventilated place or where fuel wood is used for heating of rooms. Generally, biomass smoke contains a large number of pollutants which at varying concentrations pose substantial risk to human. Among hundreds of the pollutants and irritants are particulate matters, 1, 2-butadiene and benzene (Schirnding and Bruce, 2002). Exposure to biomass smoke increases the risk of range of common disease both in children and in adult. The smoke causes acute lower respiratory infection (ALRI) particularly pneumonia in children (Smith and Samet, 2000; Ezzati and Kammem, 2001) [15. 1].

Agro waste is the most promising energy resource for developing countries like ours. The decreasing availability of fuel woods has necessitated efforts be made towards efficient utilization of agricultural wastes. These wastes have acquired considerably importance as fuels for many purposes, for instance, domestic cooking and industrial heating. Some of these agricultural wastes for example, coconut shell, wood pulp and wood waste can be utilized directly as fuels (Mangena and Cann, 2007) [7].

Fortunately, researches have shown that a cleaner, affordable fuel source which is a substitute to fuel wood can be produced by blending biomass (agricultural residues and wastes) with coal. Nigeria has large coal deposit which has remained untapped since 1950's following the discovery of petroleum in the country annually (Mohammed, 2005). But it is unfortunate that farmers still practice ''slash- and- burn'' agriculture. The agricultural wastes encountered during clearing of land farming or during processing of agricultural produce are usually burnt off. By this practice, not only that the raw materials are wasted, it further pollutes the environment and reduces soil fertility (Oyelaran *et al.,* 2017) [12].

On the other hand, the majority of the huge materials are not suitable to be used directly as fuel without undergoing some processes. This is probably as a result of inappropriate density and high moisture contents and these factors may cause problems in transportation, handling, and storage. Most of these wastes are left to decompose or when they are burnt, there would be environmental pollution and degradation (Jekayinfa and Omisakin, 2005) [5]. Researchers have shown that lots of potential energies are abounding in these residues (Fapetu, 2000) [2]. Hence there is a need to convert this waste into forms that can alleviate the problems they pose when use directly. An assessment of the potential availability if selected residues from maize, cassava, millet, plantain, groundnut, sorghum, oil palm, palm kernel, and cowpeas for possible conversion to renewable energy in Nigeria as was made (Jekayinfa and Scholz, 2009) [4]. However, these health hazard faced by people from the use of fuel wood, along with agricultural wastes management and reduction of pressure mounted on the forest can be mitigated if Nigeria will switch over to population and utilization of bio-coal briquettes; a cleaner, and environmentally friendly fuel wood substitute made from agricultural wastes and coal. Moreover, this will offer a good potential for utilization of a large coal reserve in Nigeria for economic diversification and employment generation through bio-briquettes (Onuegbu, 2010) [8].

Coal can be blended with a small quantity of this agricultural waste (agro residues) to produce briquettes (bio-coal briquettes) which ignites fast, burn efficiently, producing little or no smoke and cheaper than coal briquettes (Ward *et al.*, 2014) [17].

Thus, the studies is aimed at formulating eco-friendly bio – coal briquette from agro-waste and study how the binders affects the calorific values of the briquette through water boiling test.

Materials and Methods

The biomass wastes (groundnut shell, maize cob and rice husk) were collected from a farm in Sabon Tasha, Chikun Local Government Area of Kaduna State. The Coal was obtained from Maiganga coal seam A while the cold-water starch (from cassava) was bought from Sabon Tasha Market in Kaduna State, Nigeria.

Preparation of Samples

The biomass (groundnut shell, maize cob and rice husk) were sorted manually to remove impurities like sand, metals, and other unwanted materials. The biomass waste was sun dried for 7 days, pounded using mortar and pestle, and then sieved to a semi- fine powder of I mm. The coal and the starch were sun dried for 72 h. The coal was ground using electric milling machine and both the coal and starch were sieved separately to a fine powder of 1 mm.

Formulation of Bio-coal Briquette

About 30 g of the semi-fine powder biomass, 10 g of starch and 10 g of coal were weighed using a top loader weighing balance, into a 500 mL plastic basin. They were mixed thoroughly until a homogenous mixture was obtained and 20 mL of water was added to give a paste that can agglomerate. Starch was used as binder for some of powdered biomass pastes while in some, starch and coal as binder.

A control sample briquette was made using only the powdered biomass waste. The biomass (30 g) was weighed into the 500 mL plastic basin and made into paste using 20 mL of water without starch or coal as binder. It was left to decompose for four days in a covered plastic container. The pastes were compressed using fabricated mould and were gradually into drying plates, the resulting briquettes were sun-dried for seven days so as to become strong and firm. The samples are coded as shown in Table 1,

Table 1: Sample Codes

S/N	Sample Formulation	Sample Code
1	Groundnut Shell + Starch	A
2	Groundnut Shell + Starch + Coal	B
3	Groundnut Shell without Binder	C
4	Maize Cob + Starch	D
5	Maize Cob + Starch + Coal	E
6	Maize Cob without Binder	F
7	Rice Husk + Starch	G
8	Rice Husk + Starch + Coal	H
9	Rice Husk without Binder	I

Ash Content

The ash content (AC) was determined using standard CEN/TS 14775. About 2 g of the briquette sample was heated in a furnace at 450 ^{o}C for 1 h and weighed after cooling to get the weight of the ash (WA). The AC was determined using

$$AC\ (\%) = \frac{WA}{WS} \times 100 \quad [3]$$

Where WA is the weight of ash after cooling, and WS is the weight of the oven dried sample.

Water Boiling Test

A quantity (160 g) of briquettes sample and fire wood (160 g) were separately stacked into different briquette stove. Pots containing 1 L of water each, were placed on the briquette stoves already ignited and allowed to stabilize. The initial temperature of the water was noted using a thermometer. A stop watch was activated and readings of the thermometer were obtained at 4 min interval, this was stopped after reaching the boiling point. The same procedure was carried out for all briquette samples. The residual ashes were weighed, recorded and discarded.

Results and Discussion

Weight of Briquette and Ash

The weight of the briquettes and the ash contents are presented in Table 2. It was observed that the presence of binder (starch and coal) increased the weight of the briquette significantly. The ash contents were found to be above the tolerance level of ash content for fuel which is below 4 % (Grover and Mishra, 1995) [3]. Onukak *et al* (2017) [11] reported that high ash content decreases the burning rate and reduces the heating value of fuel. Table 2 showed that the incorporation of starch and coal reduced the ash contents of groundnut shell briquette samples significantly. This implies that the inorganic constituents of the groundnut shell briquette samples were reduced significantly by the use of starch and coal as binders in the formulation of briquettes. This suggest that for briquette samples from groundnut shell, sample B (Groundnut Shell + Starch + Coal) will have higher burning rate and heating value than samples A (Groundnut Shell + Starch) and C (Groundnut Shell without Binder). Similar result was observed for rice husk briquette samples. Sample H (Rice Husk + Starch + Coal) will have higher burning rate and heating value than samples G (Rice Husk + Starch) and I (Rice Husk without Binder). However, ash content of briquette samples from maize cobs suggest that sample F (Maize Cob without Binder) will have higher burning rate and heating value than samples E (Maize Cob + Starch + Coal) and D (Maize Cob + Starch).

Table 2: Weight and Ash Contents of the Briquette Samples

S/N	Sample Code	Biomass	Weight of Briquettes (g)	Weight of Ash (g)	Ash Content (%)
1	A	Groundnut Shell + Starch	26.98	7. 38	27.35
2	B	Groundnut Shell + Starch + Coal	35.52	7. 39	20.81
3	C	Groundnut Shell without Binder	16.44	7. 36	44.76
4	D	Maize Cob + Starch	28.57	10.99	38.47
5	E	Maize Cob + Starch + Coal	37.61	11.23	29.86
6	F	Maize Cob without Binder	19.95	4. 57	22.91
7	G	Rice Husk + Starch	36.72	11.02	30.01
8	H	Rice Husk + Starch + Coal	48.86	11.38	23.29
9	I	Rice Husk without Binder	28.52	9.82	34.43
10		Firewood		11.54	

Water Boiling Test

The cooking efficiency of the briquette samples were carried out using water boiling test. Water boiling time is a function of the volatile matter, calorific value and thermal fuel efficiency (TFE) (Onukak *et al.*, 2017) [11]. Its measure's the time required to stimulate cooking as well as other fuel characteristics of the briquette samples such as the burning rate and the specific fuel consumption during boiling phase (Owsianowski, 2009; Onuegbu *et al*., 2012) [10].

Fig. 1 showed the result of the water boiling test for briquette samples from groundnut shell. It was observed that it took longer time for the firewood and briquette without binder to boil the 1 L water compared to the time to it took briquette with binder (starch and coal) to boil the same amount of water. Firewood and briquette without binder boiled the water after 20 min while it took 16 min for the briquette samples with binder to boil the water. This implies that the burning rate or heating value of the briquette samples with binder are higher than that of the firewood and briquette sample without binder. This could be attributed to the highly combustible nature of the binders (starch and coal) as a result of their organic origin and also the additional calorific value added to the briquettes with binders as a result of the incorporation of binders. It was also observed that sample B (Groundnut Shell + Starch + Coal) boiled the water faster than sample A (Groundnut Shell + Starch) until after 8 min and this could be attributed to the highly combustible nature of coal in sample B. Fig. 1 also showed that the groundnut shell briquette without binder boiled water faster than the firewood despite both boiling the water at the same time. This could suggest low calorific value of the firewood compared to groundnut shell.

Fig. 2 showed that maize cob briquette samples boil water faster than the firewood. The maize cob briquette samples with binders (samples D and E) showed similar burning rate which results to the overlapping of their graphs. This suggests that there is no significant difference in their (samples D and E) calorific values. However, it was observed that sample D, E and F showed similar burning rate till after 8 min. Also, the maize cob briquette without binder (sample F) could not boil the water at 20 min. This could be attributed to the low calorific value of maize cob and also showed that the incorporation of coal and starch to maize cob increases the calorific value of maize cob. This finding contradicts earlier report by Onukak *et al*. (2017) [11] that high ash content decreases the burning rate and reduces the heating value of fuel. Onuegbu *et al* (2012) [10] reported that the higher the calorific values of briquettes, the higher the heat and energy released and the lesser the time required to boil water.

It was observed in Fig. 3, that rice husk briquette samples showed similar trend with groundnut shell briquettes. All the rice husk briquette samples boil water on or before 20 min. While the rice husk briquette samples with binder (samples F and G) boil water at 16 min, firewood and the rice husk briquette without binder boil water at 20 min. It was also observed that incorporation of coal as a binder did not have much effect on calorific value of the briquette since samples F and G showed similar trend by the overlapping of their graph.

It was observed generally that briquette samples without binder showed higher heating values than the firewood. This can be attributed to the high bulk density of briquettes as a result of compression during briquette production. Onukak *et al*. (2017) [11] reported that high quality fuel should have high density and strength in order to burn for a longer time and have a higher energy content. The higher the density, the higher the compressive strength.

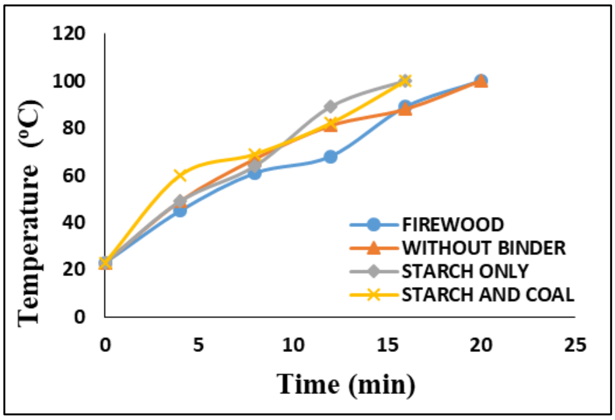

Fig 1: Burning Rate of Groundnut Shell Briquettes

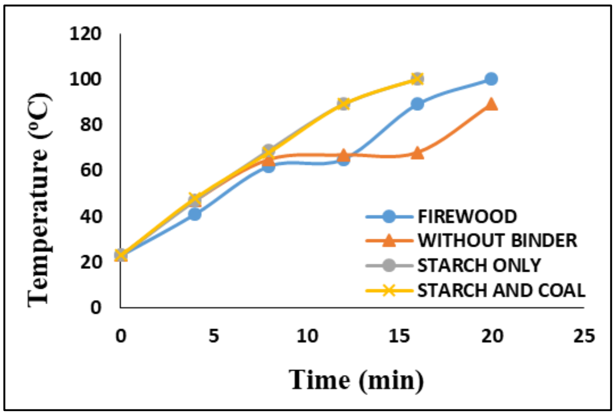

Fig 2: Burning Rate of Maize Cob Briquettes

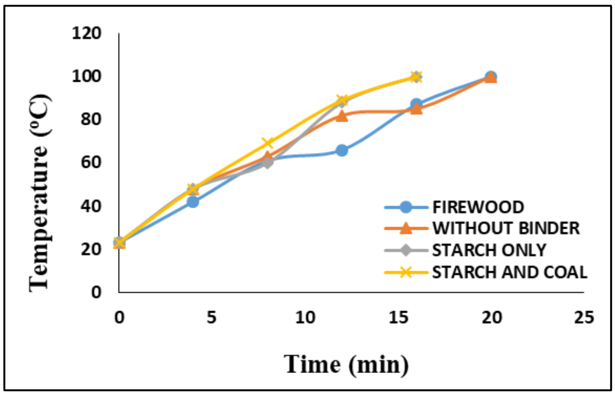

Fig 3: Burning Rate of Rice Husk Briquettes

Conclusion

In briquetting, adding a binder will not facilitate handling, storage and transportation but will also increase the calorific value of the briquettes. The result showed that briquettes will serve as a more effective substitute for firewood as it shows more combustion characteristics over firewood and the raw materials (agro – waste) are readily available. Calorific values of the agro – wastes and the incorporated binders are among factors that determine the burning rate and heating value of briquettes. Briquettes with binders has higher burning rate and heating values than the briquettes without binder and firewood as well. However, briquettes with starch and coal as binders released the highest energy value during combustion and thus, has the highest burning rate and heating value.

The conservation of the biomass into solid fuel will not only provide fuel but will also keep the environment clean. The large volume of agricultural by-products being generated in Nigeria and which constitutes environmental hazard calls for effective utilization of these high-grade biomass materials for solid fuel called briquettes.

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